Received: 20 March 2019 | Revised: 6 June 2019 | Accepted: 27 June 2019

DOI: 10.1111/csp2.95

CONTRIBUTED PAPER

Conservation Science and Practice
A journal of the Society for Conservation Biology
Open Access

WILEY

Planning for success: Why conservation programs need a strategic program for recovering species

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Funding information
New South Wales Office of Environment and Heritage Saving our Species program, Grant/Award Number: Keep Watch Review

Abstract

A substantial amount of money has been spent globally on threatened species management. While the number of threatened species continues to increase, we would expect to observe a portion of those receiving active management to respond positively and recover over time. Management of these recovering species requires a different approach to those which are declining. In particular, recovering species may require active monitoring as the primary management activity, once the threats causing their initial decline have been managed such that populations are stable or increasing. When prioritizing funding actions to improve species persistence (in particular with species prioritization approaches such as cost-effectiveness rankings), we demonstrate that monitoring species to track their continued improvement would only occur in the (unlikely) scenario of comprehensive program funding. We provide one easily implemented solution to this—the establishment of a separately funded transitional management stream within which recovering or recovered species are prioritized for monitoring from a dedicated monitoring budget. We present a set of criteria to assess recovering species eligible for this management arrangement and demonstrate the successful application of this approach in New South Wales, Australia in the Saving our Species program.

KEYWORDS

IUCN Species Green List, IUCN Species Red List Criteria, monitoring, project prioritization protocol, Saving our Species, threat management, threatened species

1 | INTRODUCTION

There is a growing call to better measure conservation success and support threatened species toward recovery (Garnett, Latch, Lindenmayer, & Woinarski, 2018; Gigon, Langenauer, Meier, & Nievergelt, 2001). While there remain significant funding shortfalls in conservation spending to meet all management needs, considerable amounts have been spent globally (McCarthy et al., 2012), and the funding to support state and national threatened species management programs is increasing in some jurisdictions (e.g., New Zealand Department of Conservation Threatened Species Program [Joseph et al., 2008], and Australian Threatened Species Management under the direction of the

Threatened Species Prospectus [Commonwealth of Australia, 2016]). With continued, and in some cases increasing, investment in threatened species programs, we would expect to see the number of recovering or recovered species increase. With a growing pool of recovering species—where the requirement for ongoing active management is reduced—it is crucial that some investment remains, with a focus on monitoring ongoing persistence. This is essential to provide rigorous data for improving the confidence around the assessment of a populations' viability, and to support species recovery processes (Akçakaya et al., 2018). If this transition from active management (with associated effectiveness monitoring) to surveillance monitoring of recovery is done in a strategic and cost-effective way, cost-savings should enable management of a larger total number of species without risking declines in the status of recovering species.

Global best-practice tools for prioritizing species management, such as the project prioritization protocol (PPP)—which have been applied to threatened species funding allocations (Brazill-Boast et al., 2018; Gerber et al., 2018; Possingham et al., 2002)—distribute funding across threatened species based on the potential "benefit" of management actions, measured by the increase in the probability of a species persisting as a result (Joseph, Maloney, & Possingham, 2009). These approaches are becoming widely applied in threatened species programs, including Australia, New Zealand, and the United States (Brazill-Boast et al., 2018; Gerber et al., 2018). While approaches to cost-effective threatened species management, such as the PPP, ensure that funds are spent to maximize the persistence of all threatened species, as formulated they cannot adequately split budgets across the shifting priorities of active management and surveillance monitoring. This is because the benefit of surveillance monitoring (characterized here as an increase in confidence, or decrease in uncertainty, around a species probability of persistence) does not align with the benefit function used to maximize management spending (the improvement in probability of persistence as a result of management) (Bottrill et al., 2008). Thus, under a constrained budget scenario, monitoring recovering species would be the lowest priority for funding and unlikely to be supported. This process is demonstrated in Box 1.

If we are to truly plan for success in threatened species management programs, agencies need to be able to confidently support the transition of recovering species toward delisting from statutory threatened species lists with the support of monitoring data. To achieve this, we offer two key recommendations:

1. *Establish transitional management arrangements for threatened species which are recovering*. Within

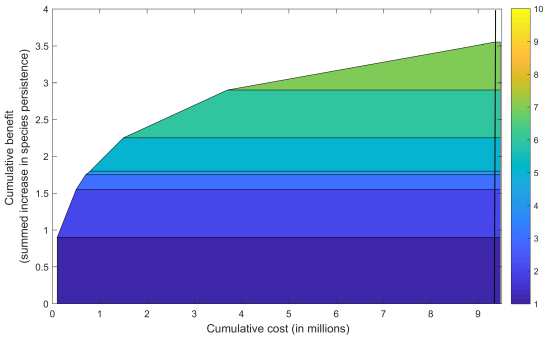
BOX 1 Transitional arrangements that support monitoring

Prioritization of threatened species management funding is commonly based upon return on investment or cost-effectiveness approaches (Brazill-Boast et al., 2018; Gerber et al., 2018). The project prioritization protocol (PPP) (Joseph et al., 2009) uses a cost-effectiveness ranking and has now been applied in a range of countries including New Zealand and Australia (Brazill-Boast et al., 2018; Gerber et al., 2018; Joseph et al., 2009).This approach is based on the objective of securing the greatest number of threatened species and the benefit of management for each species is therefore measured as the difference in the secured probability of persistence (typically set to 95% probability of persistence) and the probability of persistence in the absence of management (Di Fonzo et al., 2016; Joseph et al., 2009).

We define recovering species as those assessed as vulnerable or better, with a population size that is stable or increasing, and adequate protection within secure conservation land tenure with key threats effectively abated or the focus of ongoing management that will not cease. Recovering species, by definition, have had primary threats managed and the nominated action for these species is monitoring to ensure that they fully recover and that no further threats emerge that would impact their recovering(ed) status. However, for recovering species, the nominated action of monitoring will, by definition, have no impact on changes in persistence and therefore have no measurable benefit for the purpose of prioritization under the PPP method. Rather, the objective of monitoring, and therefore the associated benefit of monitoring recovering species, is improved knowledge and certainty around recovery. This means that if monitoring of recovering species is to be prioritized alongside threat management of species a relevant objective and benefit measure is required or a fully funded program in which *all* actions are funded is required.

To demonstrate how monitoring is only prioritized in a fully funded scenario, under the current benefit formulation, we compiled data on 10 species, listing their known critical threats, the nominated management actions to abate these threats, estimated persistence in the absence of action (P_o), probability of persistence because of these actions (P_i), estimated benefit ($b = P_i - P_o$), estimated cost (C), and the resultant cost-effectiveness score (b/c, see Appendix

S1 for all data used and ranked species based on cost-effectiveness score). The PPP method ranks species based on their cost-effectiveness score (*b/c*) and then species are selected for funding until the budget is exhausted. Of the ten species, three are recovering and their nominated action is monitoring for recovery only.



The figure above presents the cumulative costs (in millions along the *x*-axis) and cumulative benefits (summed increase in species persistence for funded species, *y*-axis) of funding species threat management at 10 different budget levels (individual colors indicate species, and species ID matches the table provided in Appendix S1). The final three budgets (indicated by the vertical black line on the graph at $9.4 million) include the monitoring of species 8–10 (recovering species) with no additional benefit (i.e., monitoring does not increase expected persistence). Monitoring these species would require $100,000 but would only be funded in fully funded budget scenarios (and see Appendix S1 for full details of costs relating to individual species projects for monitoring). This example demonstrates the need for a transitional management stream in which the objective function is to reduce the uncertainty around the estimate of probability of extinction (or persistence) and the associated action is monitoring. Such a management stream with a dedicated budget then allows managers to prioritize spending of monitoring budget across these recovering species.

transitional management, recovering species would be prioritized for monitoring with a dedicated budget. The primary aim here is to provide conclusive evidence of recovery through monitoring to reduce uncertainty around the species' likelihood of persistence. This type of monitoring should proceed for at least 5 years (i.e., the minimum timeframe to confirm recovery according to the International Union for Conservation of Nature; IUCN, 2017) or a timeframe appropriate to the taxon, prior to the species being eligible to be nominated for delisting from statutory threatened species lists.

2. *Develop and implement quantitative criteria for identifying suitable candidates for transitional management and potential future delisting*. The criteria would identify species that are recovering and for which removal or reduction in threat management will not significantly affect their extinction risk. Quantitative indicators offer conservation agencies an unbiased, evidence-based, and transparent approach to identifying species that have a particular extinction risk, or conversely a target probability of persistence (Keith et al., 2004; Mace et al., 2008).

In line with the second recommendation above, there are strong protocols in place for measuring extinction risk (Mace et al., 2008), and there is work underway to create a similar set of metrics for measuring species recovery (Akçakaya et al., 2018); however, how we identify and measure recovering species, and their trajectory toward fully recovered, remains a current research gap. As part of a collaboration with the New South Wales Office of Environment and Heritage (OEH), our research aimed to fill this gap by developing quantitative criteria to identify recovering threatened species eligible to move from active management (with associated effectiveness monitoring) to surveillance monitoring of recovery. The criteria we developed are adapted from the IUCN Species Red List Criteria, with additional components. As such, they should readily fit within existing monitoring programs or data collection efforts driven by measuring decline and recovery based upon IUCN standards for the Species Red and Green List (Akçakaya et al., 2018; Mace et al., 2008). We demonstrate why recovering species would benefit from separate management arrangements from actively managed threatened species (Box 1), and discuss some challenges associated with transitional management arrangements drawing from our experience in developing and implementing these criteria and a transitional management arrangement within the New South Wales Saving our Species program (Box 2).

2 | METHODS AND RESULTS

We hosted an initial exploratory workshop attended by relevant New South Wales OEH staff and threatened species experts. The purpose of the workshop was to review what data is currently available for threatened species in New South Wales, what type of data could be acquired in the

BOX 2 An example of a transitional management arrangement: Keep Watch

The state of New South Wales in Australia has approximately 960 threatened species listed under the NSW *Biodiversity Conservation Act 2016*. In 2013, the NSW Office of Environment and Heritage (OEH), responsible for fulfilling the state's statutory obligations to manage these species, launched the Saving Our Species program (SoS). The objective of SoS is to maximize the number of threatened species that can be secured in the wild in NSW for 100 years (Brazill-Boast et al., 2018; OEH, 2013).

All threatened species in NSW are assigned to one of six SoS management streams: Site-Managed, Landscape-Managed, Iconic Species, Data Deficient Species, Partnership Species, and Keep Watch, based on current knowledge of the species distribution, ecology, and security (OEH, 2013) (Figure 3). Management streams within SoS are divided into priority tiers and assigned an annual budget, determined by the number of species within the stream and the research or conservation actions required to ensure their security (OEH, 2013).

The Keep Watch management stream was established for species that are not considered to require immediate investment to ensure their long-term security in the wild (OEH, 2013). In 2017, SoS commissioned the authors to develop a quantitative framework to identify species suitable for Keep Watch. Those criteria and the process of their development are presented in this article. As part of this process, Keep Watch was recognized as a potential transitional management stream within SoS. Figure 3 illustrates the transitional role of Keep Watch within SoS and the path a species may follow from initial listing, toward eventual delisting (Figure 3, black and green arrows, respectively).

The function of Keep Watch will ultimately be to monitor and review each species' status periodically and in response to a number of relevant threat-based trigger events, such high severity fire in rainforest plant communities' and the arrival of infectious pathogens. The identification of downward trends or negative population responses to trigger events will spur reevaluation against the transitional management criteria (Figures 2 and 3 [red arrows]). If found to be ineligible, the species is moved back to active management in an appropriate SoS management stream (Figure 3). Species exhibiting long-term population stability or positive trends for 5 or more years may be nominated for assessment for delisting by the NSW Threatened Species Scientific Committee. Delisting processes under NSW legislation currently align with IUCN Red List standards and will increasingly incorporate Green List standards as these develop (Akçakaya et al., 2018).

As demonstrated in Box 1, when we consider the management requirements of all threatened species collectively, management actions that increase species security (e.g., threat management), will always be prioritized over monitoring under the PPP approach with a benefit function based on changes in species persistence. As such, the management stream-based structure of the SoS program is progressive. While sharing the same overarching goal, each stream has a stream specific benefit function that aligns with relevant management actions appropriate for that stream objective. Funding the streams separately allows prioritization within each stream, based on measures of benefit that are appropriate to the purpose and functionality of the stream. Project prioritization tools represent a vast improvement over ad-hoc allocation of conservation funding (Evans et al., 2016; Gerber et al., 2018; Joseph et al., 2009). In turn, the management stream approach acknowledges different conservation trajectories and customizes the application of project prioritization tools to meet these.

coming years based on new monitoring efforts, and to define what a recovering species is that would only require further monitoring rather than active management (i.e., the existing stated purpose of the Keep Watch Stream of Saving our Species, Box 2). A key outcome of the workshop was that monitoring data collected should be aligned with threatened species listing processes, and that Commonwealth and State listing processes are being streamlined to use the IUCN Species Red List Criteria. Furthermore, the IUCN Species Red List Criteria are widely applied, have been designed to correlate with extinction risk, and have been shown to be good predictors of extinction risk (Keith et al., 2004). Therefore, to ensure alignment with existing knowledge about listed threatened species and threatened species monitoring programs, criteria for identifying recovering threatened species should be based on the IUCN Species Red List Criteria.

The second key outcome of the workshop was the development of an agreed upon framework for identifying a recovering species. This framework captures the lifecycle of a threatened species from initial decline and IUCN Species Red List assessment (white portion of Figure 1), to active

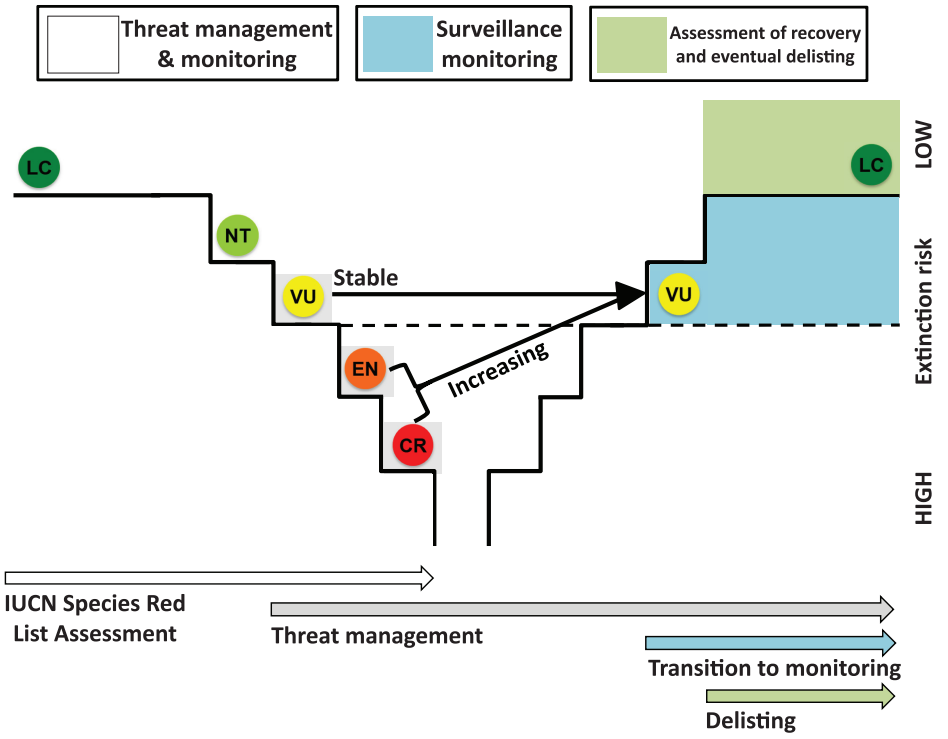


FIGURE 1 Life cycle of a species from decline and listing as threatened (white portion of figure), recovering (via active management [gray portion of figure], and then monitoring [blue portion of figure]), to recovered and eventual delisting (green portion of figure)

threat management and population stabilization/increase with associated monitoring of the effectiveness (gray portion), to surveillance monitoring of recovery (blue portion), and eventual delisting from statutory threatened species lists (green portion). The critical transition from management of threats and monitoring of effectiveness of actions to surveillance monitoring of recovery once a population has increased or stabilized, relies on threats being abated and the species being under secure management arrangements. At this stage there is no further threat management requiring resourcing and the population needs time to recover in response to the threat management (e.g., Hamilton, Turner, Rendell, & Downey, 2010). During this phase (blue portion, Figure 1) active monitoring is required to ensure the population is recovering as expected. Monitoring during this phase may also include a capacity to report the emergence of new threats or reemergence of preexisting threats. Over time, in the absence of stochastic events or new emerging threats, it would be expected that these species would fully recover and be eligible for delisting from statutory threatened species lists (green portion, Figure 1). This narrative captures three elements that define a recovering species: first, the species is assessed as Vulnerable or better; second, the species' population size is stable or increasing; third, the species is adequately protected within secure conservation land tenure within which key threats are either effectively abated or the focus of ongoing management that will not cease.

To assess a species as "threatened" (and formally list it), "recovering" (and assign it to active monitoring), or "recovered" (and ready for delisting), quantitative measurable criteria are required (Figure 1). For instance, the IUCN Species Red List Criteria provide an explicit, quantitative and objective framework for classifying species according to their extinction risk, based on species range and population attributes and measures of decline (Mace et al., 2008). Similarly, forthcoming refinements of the recently published Species Green List approach will allow for quantitative assessment of species recovery (Akçakaya et al., 2018).

Based on our framework that defines the elements of a recovering species, we developed criteria to identify recovering species suitable for transitional management arrangements. These criteria are directly aligned with the IUCN Species Red List Criteria to ensure that processes of assessment (from decline through to recovered) are streamlined reflecting the key operational requirements of our government partners within NSW OEH.

Our criteria for assessing a recovering species for placement into transitional management are presented in Figure 2 with a glossary of related terms and concepts in Appendix S2. The first element of a recovering species is that it is Red Listed as vulnerable or better. By limiting transitional management to IUCN vulnerable species, we include recovering species, but exclude species in earlier stages of recovery which may still face a high or very high risk of extinction (i.e., endangered and critically endangered species, respectively). Our Criteria (1–3) for assessing a species as vulnerable or better are a simplified version of the IUCN Species Red List Criteria (see Appendix S3 for further methodological details).

Eligibility criteria for transitional (monitoring only) management

Transitional management is appropriate for threatened species that have demonstrated population stability or improvement and no longer require targeted management activities aside from monitoring to 1) ensure populations are recovering and 2) to identify potential threats to the security of the species. EC1, 2 and 3 are based on **IUCN Red List criteria** and require the species to meet thresholds for Vulnerable or better, allowing for time lags between effective management and positive population responses. EC4 reflects that the population must be stable or increasing. EC5 is based on protection and critical threat abatement, and the security of those arrangements. **Blue boxes** outline the rationale underpinning each criterion

To qualify for the transitional management stream a species must meet ALL FIVE of the following criteria:

EC1. Historic population decline ceased, and not too large

In the case of past population reduction which was observed, estimated, inferred, or suspected, where the causes of the reduction are clearly reversible AND understood AND have ceased, **the population has not reduced by 70% or more over a timeframe appropriate for the taxon**

A reduction in population may be measured based on a) direct observation b) an index of abundance appropriate to the taxon, c) a decline in area of occupancy (AOO)*, extent of occurrence (EOO)* and/or habitat quality, d) actual or potential levels of exploitation, or e) effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.

Vulnerable or better IUCN A

This criterion simplifies IUCN Criteria A, which ensures the species has not demonstrated rapid decline in the recent past. To meet EC1, the causes of decline MUST be understood, be reversible, and have ceased. IUCN recommends 3 generations or 10 years (whichever is the longer) as an appropriate timeframe to assess historical population declines.

EC2. Distribution is not significantly restricted, fragmented or unstable

If the species geographic range is less than 5,000km^2 (EOO) or 500km^2 (AOO) **then the species must NOT have BOTH of the following:**

i. A severely fragmented* distribution **AND**
ii. Extreme fluctuations* in any of EOO, AOO, number of locations* or subpopulations* or number of individuals

This criterion is based on IUCN Criterion B which aims to ensure that species with restricted ranges are not also demonstrating (or likely to demonstrate) continuing population decline, severe fragmentation and extreme and unsustainable population fluctuations. As stable or increasing populations are a prerequisite for a monitoring-only transitional management stream, population decline as defined by IUCN has been removed from this criterion.

Vulnerable or better IUCN B

EC3. Population is not too small, *including all the following*:

a) The species is present at 3 or more locations* **AND**
b) AOO is 20km^2 or greater **AND**
c) The species has greater than 1000 individuals in the total population

This criterion has the same function as IUCN Criterion D, which sets minimal number of locations, AOO and population sizes for very small or restricted populations to reduce the risk of extinction via stochastic threat events, and ensure population viability. A population of >1000 individuals is considered essential for retaining evolutionary potential*. Expert knowledge should identify where a higher (or lower) population threshold is more appropriate.

Vulnerable or better IUCN D

EC4. Population is stable or increasing

Population trajectory data* show evidence of stable or increasing populations across an *adequate proportion*[1]* of the range

This criterion requires scientifically robust monitoring data as evidence that the species has responded positively to management.

EC5. An *adequate and representative proportion*[1] of the species range is within secure conservation land tenure within which the species critical threats are abated or being *adequately managed*[2] *including all of the following:*

a) An adequate and representative proportion[1] of the species range comprises secure conservation land tenure* (including formally protected areas, conservation management sites and land covenanted in perpetuity) **AND that either:**
   i. The species critical threats are abated* by being situated in secure conservation land tenure **AND/OR**
   ii. Evidence shows that critical threats are being, and will continue to be, adequately managed* within these sites

This criterion aims to ensure a high likelihood of the species ongoing security by requiring that an adequate proportion (as defined in EC1) of the species range is within secure conservation land tenure and not exposed to critical threats. Extensive tracts of intact habitat enhance species' adaptive capacity and resilience to threatening processes. Furthermore, conservation infrastructure and established management frameworks associated with formally protected areas, facilitate the appropriate monitoring of populations and the identification of impending threats to the security of the species, which may prompt reassessment. For i.) critical threats including habitat loss and fragmentation, land clearing and livestock grazing are (in most cases) effectively abated by being in secure conservation land tenure. For ii.) in the case of landscape-wide pervasive threats such as altered fire regimes, weed invasion and pest animals, evidence of ongoing management across the adequate proportion of the range is required.

[1] An adequate and representative proportion of the species range is that considered as necessary for the species to have <5% extinction risk, and should be guided by IUCN Red List.

FIGURE 2 Eligibility criteria for transitional management arrangements

We developed two additional criteria, in consultation with NSW OEH staff after our workshop, to reflect the second two elements of our definition of a recovering species (Figure 1). Criterion 4 states that population monitoring must show that the population is stable or increasing. Criterion 5 requires that an adequate and representative proportion of the species range comprises secure conservation land tenure (including formally protected areas, conservation management sites, and land covenanted in perpetuity) and that within this range, key threats are either effectively abated or remain the focus of ongoing management independent of listing status. This criterion reflects the fact that active protection and management have resulted in the species recovery and that to ensure continued persistence of the species, these management arrangements should be secure with evidence that they will continue. The bounds of "adequate" protection and management are species-specific and expected to be set based on data or expert driven determination but typically ranging from 30 to 100% of the species' "indigenous" range (Akçakaya et al., 2018; Fahrig, 2003; Groves, 2003) (Appendix S2). "Representative" protection spans the full range of abiotic conditions, ecosystems, and communities across the species range (Akçakaya et al., 2018), and supports species' adaptive capacity in the face of major threats like climate change by maximizing protected suitable habitat. Similar to "adequate," any assessment of "representativeness" will be species-specific and will also be highly dependent on how environmental variation is partitioned, which may be subjective.

3 | DISCUSSION

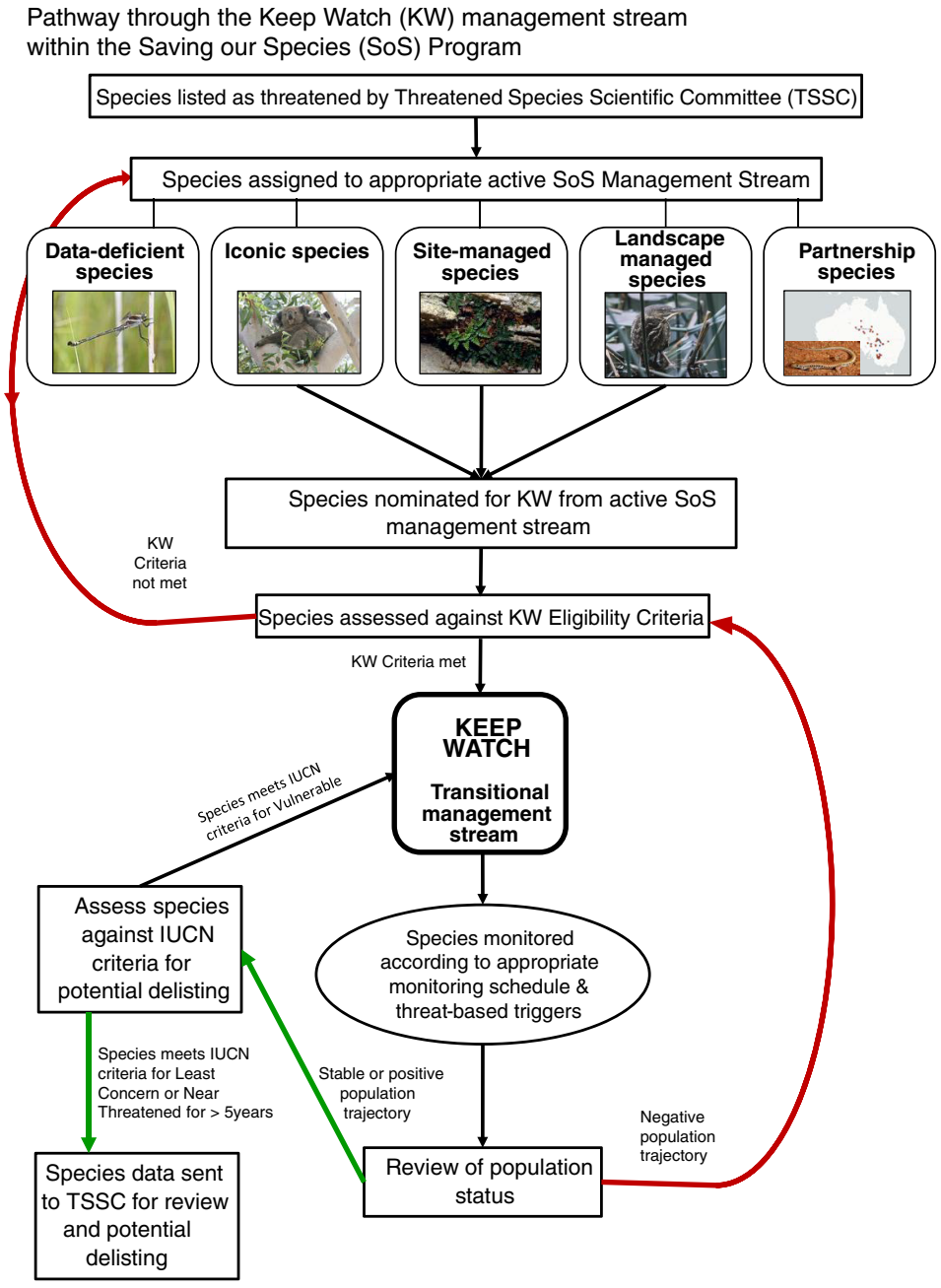
The recovery and eventual delisting of species is reliant on resources to effectively monitor populations to gather evidence required for clearly demonstrating sufficient recovery and ongoing security (Figure 1). Here, we have demonstrated how project prioritization tools used to allocate limited funding to conservation actions will always rank monitoring populations of recovering species as low priority, as it confers no improvement in the species' likelihood of species persistence (Box 1). We provide one easily implemented solution to this—the establishment of a separately funded transitional management stream within which recovering or recovered species are prioritized for monitoring from a dedicated monitoring budget. Our criteria (Figure 2) identify suitable threatened species for this transitional management arrangement and align with IUCN Red and Green List criteria.

We demonstrate this approach in practice in the New South Wales Saving our Species program where the concept of a transitional management arrangement and the associated criteria will be applied through the Keep Watch management stream (Box 2). A preliminary assessment has been conducted which identified 62 species (of 102 originally allocated to Keep Watch) as candidates for transitional management (Gallagher, Adams, O'Donnell, Lawson, & Laws, 2018). In the Keep Watch stream these species can now be prioritized for monitoring. Further monitoring data aligned with the criteria presented in this article will both confirm their status and provide the required data to ensure that they continue to recover or recovery completely. We present below some key characteristics of the species that qualify under our criteria and challenges and opportunities emerging from the Keep Watch experience that are broadly applicable to any threatened species program applying our proposed transitional management approach and associated criteria.

3.1 | Characteristics of species eligible for transitional management

The criteria ultimately identify two distinct types of species as suitable for transitional management. The first are potential delisting candidates, and the second are naturally rare species with highly restricted ranges. Delisting candidates would be monitored until, according to current IUCN guidelines, evidence indicates the species qualifies as IUCN category "Near Threatened" or "Least Concern" for at least 5 years or a timeframe appropriate to the taxon (IUCN, 2017). At this point evidence will be sufficient for delisting from statutory threatened species lists which are sufficiently aligned to IUCN criteria (e.g., the NSW Biodiversity Conservation Act). Pre-delisting assessment could also follow the recent Green List approach, which expands measures of recovery through consideration of species functionality, and the impact of conservation activities on past, future, and potential recovery (Akçakaya et al., 2018).

Naturally rare species are typically those with highly restricted ranges (e.g., many are adapted to highly restricted ecological or environmental niches). Even when these species have genetically viable populations (e.g., >1,000 individuals; Frankham, Bradshaw, & Brook, 2014), they will qualify as Vulnerable for IUCN criteria D2, if they are found at fewer than five locations and a plausible future threat could drive the taxon to critically endangered or extinct in a very short time. Such naturally rare species may remain threatened, despite having their key threats abated or managed, due to their risk of extinction or extirpation from plausible but potentially rare catastrophic events such as landslide (Brown, 1995; Mace et al., 2008). For such species, the objective of monitoring within transitional management is not to support delisting, but rather to periodically assess population stability and population responses to specific threat-based trigger events that threaten the security of these populations. Triggers may include an adverse fire event or regime, severe drought, or the arrival of specific pathogens or disease and are distinguished from landscape-wide, pervasive threats such



Images from left to right: Coastal Petaltail (*Petaluralitorea*), Koala (*Phascolarcto scinereus*), Rock Shield Fern (*Polystichummoorei*), Black Bittern (*Ixobrychus flavicollis*), Wedgesn out Ctenotus (*Ctenotusbrooksi*). ©NSW Office of Environment and Heritage

FIGURE 3 The role of the Keep Watch transitional management stream within the NSW Office of Environment and Heritage Saving Our Species program

as weed invasions and feral predators which are routinely managed within most protected areas. If post-trigger event-monitoring detects a negative population response, eligibility to remain in transitional management should be reassessed, and the species should be moved back to active management (e.g., see Box 2, Figure 3, red arrows).

3.2 | Challenges associated with the transitional management approach

Ensuring the ongoing recovery and security of threatened species that are in transitional arrangements or under consideration for delisting is crucial. Delisting failures—when species decline post-delisting, and require relisting—are not uncommon and risk undermining the perception of conservation in the wider community. For instance, the Yellowstone grizzly bear and gray wolf were both relisted in the United States after significant population declines post-delisting (Anderson, 2013). The Australian ghost bat, woylie, and grass wren have also suffered similar fates (Department of Environment and Energy, 2018). Such failures have resulted, at least in part, from inadequate monitoring and measurement of the species' recovery and/or inadequate quantification of the ongoing security of the

species when legislative protections are removed by delisting (Anderson, 2013; Groom, 2010).

Protected areas remain the cornerstone of threatened species conservation and (in Australia) generally offer effective protection against key threats including land clearing and livestock grazing where the exclusion of these activities is upheld (Taylor et al., 2011). Most recovering and recovered species will depend on the ongoing management of landscape-wide pervasive threats, such as weeds, herbivores, and predators (Akçakaya et al., 2018; Goble, Wiens, Scott, Male, & Hall, 2012; Groom, 2010). Ensuring that an adequate and representative proportion of the species range is within secure conservation-orientated land tenure—such as protected areas—maximizes the likelihood that the status of commonly occurring threats are monitored and managed as required (Kearney, Adams, Fuller, Possingham, & Watson, 2018). For example, in Australia, IUCN-classified Types I–IV reserves offer protection from stressors including recreational hunting, land clearing, and livestock grazing, which cannot be guaranteed within other land tenures (Dudley, 2008; Kearney et al., 2018; Watson et al., 2011). Considering regional differences in both legislative protections and the level of protection offered within protected areas, estimating the potential impact of the loss of legislative protections should be an essential component of any delisting assessment (Akçakaya et al., 2018; Goble, 2009).

The greatest barrier to the establishment of transitional management streams will be securing funds to monitor the populations within them. As budgets for monitoring will undoubtedly be limited, frameworks to optimize and prioritize monitoring across recovering species will be essential (Regan et al., 2007; Wintle, Runge, & Bekessy, 2010). For example, project prioritization tools could be modified to accommodate alternate measures of benefit (e.g., "Value of Information" [Yokota & Thompson, 2004]) and likelihood of success relevant to recovering species and the collation of evidence to support delisting (Bottrill et al., 2008; Joseph et al., 2009). Focal species or indicator surrogates for functional groups of species with similar threats and responses could be monitored to assess the impact of routinely managed landscape-wide pervasive threats. Finally, the identification and integration of relevant threat-based triggers for monitoring into prioritization frameworks will be necessary to ensure the ongoing security of rare and/or restricted populations within transitional management (as discussed above).

4 | CONCLUSIONS

The criteria presented here to identify recovering species are widely applicable and directly aligned with IUCN criteria for identifying threatened and recovered species. As such they can be applied by any threatened species management program that wants to identify species that are on track and recovering. One reason to do this is to ensure that management efforts shift to surveillance monitoring, ensuring rigorous data is available to track species and support eventual delisting. Equally, a strategic framework to identify recovering species that no longer require active threat abatement (generally far more expensive than surveillance monitoring) will liberate management funding to support management of new and emerging threatened species. The process of allocating funds can be supported with widely applied prioritization approaches such as the PPP. However, as demonstrated here, the use of tools such as the PPP require the definition of a relevant management objective, benefit function, and aligned management actions. These management objectives need to respect the distinction between monitoring to improve certainty around population status (and indeed other types of learning, e.g., adaptive management), and management to improve probability of persistence. Transitional management arrangements for recovering species are a transparent approach for decision making across the life cycle of threatened species management from listing through to recovery.

ACKNOWLEDGMENTS

We thank Mark Hamilton, James Dawson, Alison Curtin, Jane DeGabriel, and Renee Hartley of the NSW Office of Environment and Heritage for feedback on the Keep Watch review process and Keep Watch Review workshop attendees who assisted with developing the ideas presented.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

All authors contributed to the conception of this work and writing of the manuscript. V.M.A. led writing of the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: Adams VM, O'Donnell J, Burley A, et al. Planning for success: Why conservation programs need a strategic program for recovering species. *Conservation Science and Practice*. 2019;1:e95. https://doi.org/10.1111/csp2.95